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THEMED ISSUE ARTICLE

The challenges and opportunities of open-access microscopy facilities

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Abstract

Microscopy core facilities are increasingly utilised research resources, but they are generally only available to users within the host institution. Such localised access misses an opportunity to facilitate research across a broader user base. Here, we present the model of an open-access microscopy facility, using the Advanced Imaging Center (AIC) at Howard Hughes Medical Institute Janelia Research Campus as an example. The AIC has pioneered a model whereby advanced microscopy technologies and expertise are made accessible to researchers on a global scale. We detail our experiences in addressing the considerable challenges associated with this model for those who may be interested in launching an open-access imaging facility. Importantly, we focus on how this model can empower researchers, particularly those from resource-constrained settings.

KEYWORDS

core facilities, equitable access, open-access microscopy, technology dissemination

1 | INTRODUCTION: WHY OPEN-ACCESS?

There are several reasons an institution would grant external scientists access to the microscopy instruments available in their core facilities. First, highly advanced techniques such as super-resolution microscopy, fluorescence lifetime imaging, and specialised label-free microscopy, while powerful in their own rights, are often niche methods that may not be appropriate for a broad range of biological applications. These instruments tend to have extra capacity that can be offered to external users to help defray the maintenance cost. Second, the rate of imaging technology development has far outpaced the commercialisation process, resulting in many potentially transformative instruments remaining in the labs in which they have been developed, unless they are shared through open-access programs.[1] In turn, exposing researchers to new technology can pave the way for easier commercialisation in the future. Third, microscopy networks on the regional, national, and global scales are increasingly seen as a valuable means to disseminate technology to a larger user base, and to pool resources. Thus, joining such networks implicitly requires an open-access model.[2–7]

Technology accessibility can be accomplished through multiple avenues. These include the (1) Imaging by courier model.[8] In this approach, users ship specimens to the imaging centres, where local application scientists perform experiments with or without the external users present, often relying on remote collaboration to guide the project. This model increases accessibility by easing the burden of travel (both cost and time) and is invaluable in times of extensive international travel restrictions such as those imposed during the COVID-19 pandemic. However, it is limited by what projects can reasonably be handled by the local imaging scientists who may not have the necessary

FIGURE 1 Major considerations when instituting an open-access imaging core facility.

expertise to handle a wide variety of complex specimens. One approach to facilitate access to advanced microscopes while allowing life scientists to perform complex experiments in their own labs is to adopt the (2) Traveling microscopes model.[9] In this approach, microscopes tailored to be easily assembled and withstand multiple rounds of shipping are sent to end users by request. Upon completion of the experiment, the instrument is repackaged and shipped to the next user. As expected, this model is severely restricted as most microscopes cannot be easily relocated. Lastly, the (3) Visitor program model offers a platform on which visiting groups perform experiments at a location away from their home institution. This approach is well suited for experiments that require significant local technical commitment and advanced microscopes that cannot be easily moved. The pitfalls of this approach include the need for substantial institutional support, low user throughput, travel cost, and more importantly, inequitable accessibility due to the expectation of strong preliminary data that may bias towards users from affluent regions. Additionally, a sudden change in global travel patterns, as exemplified by the COVID-19 pandemic, can profoundly disrupt operation. While none of these models are superior to the others, the visitor program approach, spearheaded by multiple groups – including Euro BioImaging and the Advanced Imaging Center (AIC) at HHMI Janelia Research Campus has gained considerable popularity and will be the focus of this discussion.[1,5]

In this paper, we examine the challenges and pitfalls of running an imaging centre with an international open-access visitor program, as well as operational solutions to these issues, using the AIC as a model. In the following discussions, it is important to note that the AIC serves a global user base, under a fully funded model that covers visitor housing, instrument, and staff time, as well as basic experimental costs. This discussion, however, is intended to be applicable to a wide range of open-access core facility models – such as those with a national or regional user base and/or those that rely on user fees for cost recovery. Throughout, we refer to 'visiting users' or 'external users' as any researchers wishing to gain access to an imaging core facility that is outside their home institution. Figure 1 outlines the considerations that will be covered throughout this discussion. Importantly, we also offer insights into how a visitor program can be translated for resource-challenged regions of the world, creating potentially high-impact, open-access facilities that can be leveraged to address the inequitable distribution of research infrastructure.

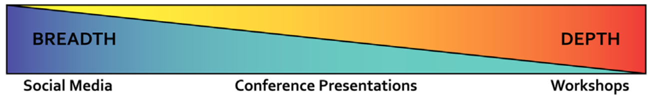

FIGURE 2 Inverse relationship between breadth and depth of communication strategies for generating awareness of an open-access imaging facility.

2 | GENERATING AWARENESS: IF YOU BUILD IT, THEY WON'T COME

Among the various open-access platforms, some have elected to grant admission by invitation. While this does not require a concerted outreach effort, such exclusivity risks missing opportunities to serve high-impact science from researchers outside of a siloed network and excludes researchers who do not have an existing relationship with the imaging centre or its active user base. For other approaches that aim for broader audience engagement, it is a common fallacy to assume that advanced technology alone is sufficient to draw external users to a shared resource. Consequently, the creation of such open-access resources is often coupled with a concerted advertising effort, including press releases, social media blitzes, and email blasts to showcase the technologies to the widest possible audience. Such superficial communication (commonly known as the 'spray and pray' approach) is often devoid of the necessary depth to effectively engage the prospective user base. This common failure is due to the inevitable trade-off in messaging between the breadth of reach and the depth of engagement (Figure 2). For researchers to fully appreciate how technologies can impact their projects, a sustained, often in-person,

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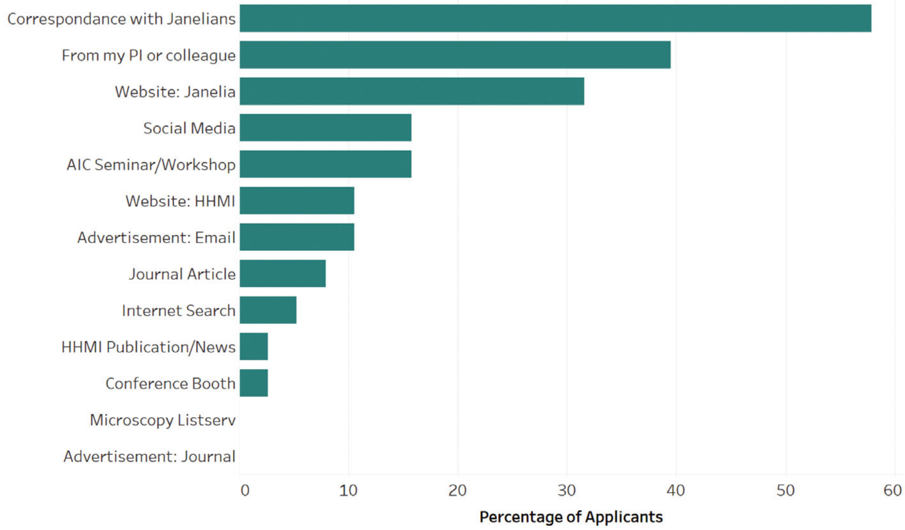

FIGURE 3 Results of survey that asked how recent applicants became aware of the Advanced Imaging Center at Janelia Research Campus. Note that the survey allowed respondents to select multiple answers, so the sum of percentages is greater than 100%.

strategy is required. Core facility staff should embrace the role of ambassadors through presentations at symposia, workshops, conferences, and other forums outside their home institution. Recognising and creating such opportunities should leverage a range of resources, including current and former facility users, professional associations, as well as microscopy user communities and infrastructure networks.[3,4,10–12] However, special care should be taken to ensure that awareness is spread equitably. It is vital to connect with research communities that have historically been marginalised due to institutionalised unconscious bias. This includes those from resource-constrained geographical regions and underserved institutions, such as primarily undergraduate- or minority-serving universities in otherwise affluent areas. Failing to connect with these communities risks alienating a vast talent pool, and ultimately reduces scientific impact. In this way, organisations that serve underrepresented researchers and resource-constrained regions are invaluable for broadening awareness.[6,11,13]

A survey of recent applicants to the AIC revealed that most became aware of the facility via word of mouth, either from Janelia researchers, or other colleagues (Figure 3). The second most common means was through website and social media engagement. Workshops and seminars represented a third common route. Critically, workshops and seminars were found to be the most likely means to generate applications from underrepresented communities, illustrating the vital role played by such targeted, resource-intensive initiatives in opening access to these often-excluded researchers.

Regardless of the particular outreach route, we advocate for a 'project-centric', rather than a 'technology-centric' approach when communicating with potential external users. It is more important to convey to end users how a certain technology can address their experimental problem, rather than its specific technical capabilities. One way of framing a project-centric approach is by asking, 'How could life scientists outside the institution benefit from the technology available in this core?' Failing to provide compelling biological contextualisation of imaging technology risks losing potentially transformative projects.[13]

3 | VISITOR TECHNICAL CONSULTATIONS: THE KEY TO SUCCESS

To translate the initial excitement among potential visitors to subsequent experimental success, a technical consultation is essential. In fact, these consultations often form the primary basis for an overall project management and user interaction plan.[8] Core facility staff should always schedule time with prospective visitors to discuss a project in depth before finalising their experimental design. Failure to preemptively recognise critical flaws and identify potential improvements in a visitor project will result in considerable wasted time and expense between both parties. This is, of course, good practice for both internal and external users; however, a technical consultation for an external visitor is particularly crucial, as there are unique aspects to consider. Furthermore, a technical consultation offers an invaluable opportunity to provide additional support for applicants – particularly those from underserved communities through in-depth technical guidance and feedback. This not only acts as a means for establishing clear expectations among both visitors and core facility

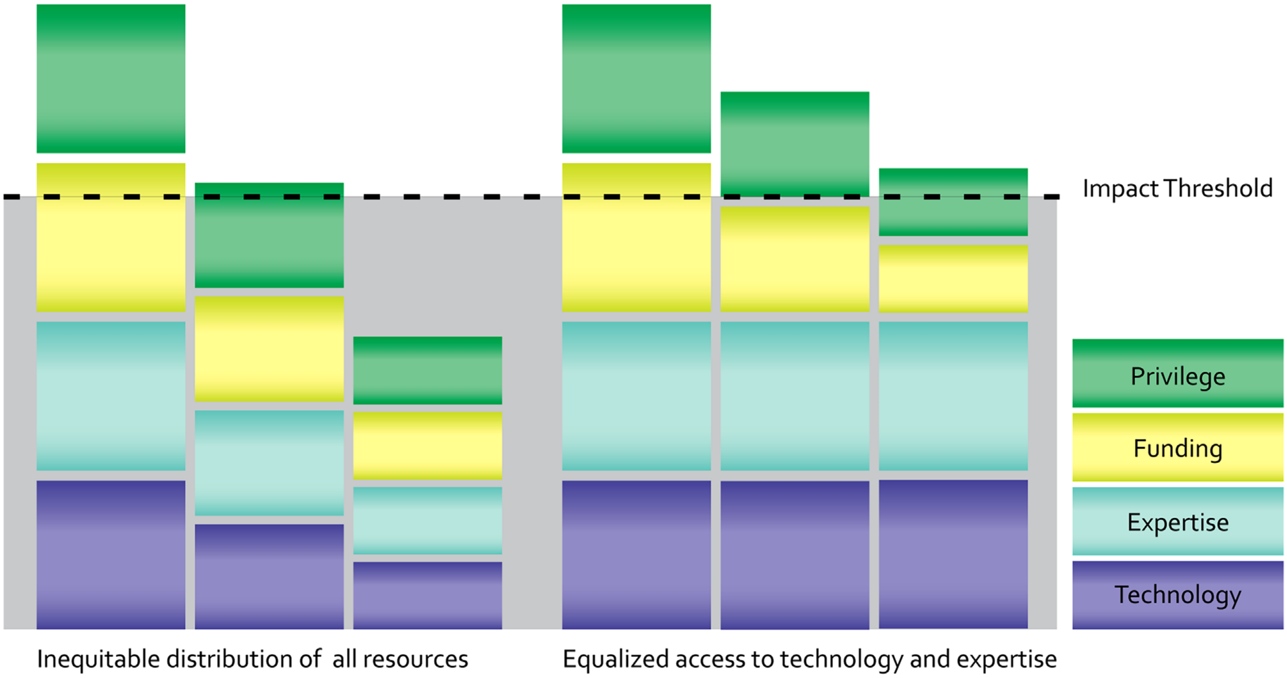

FIGURE 4 Equalising access to imaging technology and expertise increases the likelihood of scientific success despite inequitable distribution of funding and privilege.

staff, but also serves as a valuable way to educate prospective users on various aspects of microscopy experiment design and implementation.[14]

3.1 | Is the project feasible?

First and foremost, the technical feasibility of the proposed experiments should be carefully evaluated with the prospective visitor. As with an internal user, questions of sample compatibility with the instrument, including mounting requirements, labelling protocols, and biosafety considerations should be carefully assessed. Further, the prospective user's understanding and expectations of instrument capabilities, core facility support, and the role and workload of facility staff should be critically discussed in relation to their scientific questions. This is especially important for external users who may (1) be working in a biological field that is unfamiliar to imaging facility personnel, (2) lack knowledge of the imaging facility technologies, and (3) be unaccustomed to limited-term, intensive imaging projects. Overall, an effective way to assess the technical barriers faced by a potential user at their home institution is to evaluate their existing imaging data, with an eye towards identifying both the information it contains as well as its limitations.

In addition to its technical feasibility, an external visitor project will present unique logistical and practical considerations that can limit its feasibility. Such visits are, in general, limited in time due to travel costs and other issues. Consequently, wide-ranging projects with multiple technical aims, samples, and experimental conditions may not be suitable. For example, AIC visitors spend, on average, two weeks collecting data with an Application Scientist dedicated full-time to the visiting scientists to address a small set of specific aims. This level of staff support is necessary, in part, due to the complexity of the instrumentation in the centre. However, imaging facilities with more user-friendly instrumentation and/or more limited requirements for pre- and postvisit support may not require such time-intensive support for visitors. Nevertheless, given the often-compressed time schedule, a majority of at least one staff member's time should be allotted for the duration of a visit in almost every case. Sample shipment/receiving and maintenance prior to the visit (discussed in further detail below) present an additional demand on staff and resources that should be also evaluated at this stage. To help estimate the resources needed to support a project, it is imperative that visitors articulate a detailed, achievable plan before a project is approved. A technical consultation offers a prime opportunity to discuss, and often narrow, the focus of a proposed project in light of the time and resource constraints that both visitors and imaging facility staff face.

Finally, imaging technologies often generate an overwhelming volume of data that is not always anticipated by the end user or imaging facility, even while data acquisition is ongoing. This can pose a potentially insurmountable problem after completion of a visit. Therefore, data handling and storage – both at the host facility and at a visitor's home institution – should be discussed at the technical consultation phase to identify future bottlenecks. Furthermore, if data processing and analysis support is offered by the imaging facility, the feasibility of a project can also hinge on the availability of staff and computational resources. This issue is critical and will be discussed in greater detail in a subsequent section.

3.2 | Is the project justified?

It is common for a technical consultation to reveal that improvements in experimental design, sample preparation, and/or data quantification can overcome user challenges, rather than a more advanced microscope. In such cases, imaging facility personnel should carefully evaluate the justification for hosting an external visitor. On one hand, valuable instrument time should ideally be reserved for experiments that best take advantage of the system capabilities. On the other hand, with careful technical guidance, a proposed project may be enhanced or expanded beyond its initial goals such that it makes better use of the microscope. Weighing the appropriateness of a project can often equally involve strategic and technical considerations. If the instrument in question is already heavily used, or staff time is heavily limited, the threshold for justification may need to be stringent. If there is sufficient spare capacity, however, more flexibility may be employed. In any case, the importance of a technical consultation cannot be overstated. Properly identifying the goals, potential pitfalls (and possible remedies), as well as likely post-visitation needs before a project begins is the single most effective way to bring a project to fruition. It also offers the best means to educate users on both the power and limitations of imaging technologies, as well as what can, and cannot, be deduced from the resulting data.

4 | VISITOR SELECTION: CHOOSE WISELY

Once a technical consultation has been performed, a decision of whether to accept an external visitor must be made. If demand for facility resources exceeds availability, a selection process must be implemented to maximise effective and efficient equipment usage. Further, one must consider whether rules imposed by the host institution or its external funding sources restrict the type of projects that may be hosted in a facility.[15] Conversely, institutional policies may require acceptance of all proposals that are technically feasible and can be safely hosted in the facility.

Unless a facility receives only occasional requests for external projects, it may be necessary, despite the increased time and effort required, to implement a proposal-based selection process. When establishing such a system, the most critical step is to determine the metrics that will be used for evaluating proposals. For example, these criteria can include (1) a justification for use of the chosen microscope, (2) feasibility of the project, (3) scientific merit, and (4) institutional biosafety and support considerations. This list is not comprehensive, but rather serves as a starting point for developing one's own evaluation criteria. It is equally important to communicate these criteria to applicants so they can tailor their proposals accordingly. After the evaluation criteria are chosen, a second consideration is whether the proposals will be peer reviewed by an independent committee. Peer review and evaluation are especially useful when assessing metrics such as scientific merit. However, such a system requires active participation from leading scientists outside of the imaging facility. Additionally, having a plan for rapid resubmission of proposals is essential. Oftentimes, excellent proposals have a single critical flaw that can be easily rectified; a rapid resubmission process will protect against the outright rejection of such proposals.

It may be tempting to assume that a competitive, peer-reviewed proposal process with clear and uniform evaluation criteria is the most equitable means for selecting external users. In practice, however, the AIC has found that doing so consistently results in the exclusion of projects from resource-constrained settings. By selecting projects with the highest technical feasibility, strongest preliminary data, and most compelling justification, proposals from more affluent communities tend to gain a competitive edge over their counterparts in resource-challenged areas. This dilemma demands a re-examination of the metrics of success for every imaging centre that engages in open-access technology dissemination. Failing to do so risks creating an open-access resource that is, in fact, antithetical to the principles of open science. The AIC strives towards a balanced approach when evaluating proposals. For example, applicants are always encouraged to supply preliminary data to support the feasibility and justification for their proposed projects. However, this is always weighed in light of the resources available to users, particularly those in resource-constrained settings.

5 | PREVISITATION LOGISTICS: HOPE FOR THE BEST, PREPARE FOR THE WORST

Once a project has been accepted, there are two logistical and technical considerations before any experiments begin: (1) ensuring the safe arrival of the visitors and their specimens and (2) preemptive technical troubleshooting. In both instances, efficiency and transparency are paramount.

The very nature of an external visitor-based imaging centre demands a compressed time schedule. These time constraints dictate that before specimens are shipped or travel arrangements made, all reagents and necessary protocols must be tested to the extent possible at the home institution and the results shared with the imaging centre. Doing so limits troubleshooting of the experiment only to the aspects that must be performed during the visit. Moreover, these discussions provide an opportunity to finalise a detailed plan for the visit, which is critical for maintaining focus throughout the stay. Once the experimental plan is established and any technical concerns are addressed, it is then time to consider the logistics of arrival.

In preparation for the project, the visitor should produce a comprehensive list of all specimens, reagents, and supplies that will be required to support the experimental plan. This accounting should be as detailed as possible to avoid unnecessary delays during the visit. The imaging centre staff and visitors should jointly and clearly establish which materials will be provided and which need to be shipped to the imaging centre.

There is a broad range of potential difficulties in shipping biological specimens and reagents. It is advisable for the imaging facility personnel to guide visiting researchers through this process to ensure proper procedures are followed. In the simplest case, such as intranational shipping of nonhazardous reagents, there may be few legal barriers to navigate. Nevertheless, one must still (1) establish when and by whom the shipment will be received, (2) ensure visitors properly package shipment to maintain viability of reagents and specimens, (3) require protocols for maintenance of the samples and storage of reagents be provided before the shipment arrives and (4) recommend a second set of specimens and reagents be ready to ship should the originals become lost or damaged in transit. Though seemingly trivial, this level of preparation is fundamental to ensuring a smooth start to a visit. For more challenging scenarios, such as transcontinental shipping of transgenic animal models, there is a bevy of regulations and institutional requirements that must be followed. Due to the vast and cumbersome nature of these regulations, we strongly recommend that the imaging centre staff partner with their local animal care and environmental health and safety specialists. While a full catalogue of potential regulatory and logistical issues is beyond the scope of this discussion, there are practical ways to avoid many challenges. For example, many regulated specimens and reagents can be procured through stock centres and retailers within the imaging centre's home country in order to avoid difficulties with international shipping. In summary, the seemingly simple act of transferring specimens and reagents is rife with potential points of failure that can prevent an otherwise carefully planned visitation from proceeding.

With a system in place for receiving biospecimens, reagents, and other materials, plans must be made for the arrival and lodging of the visitors themselves. The AIC provides free on-site housing at the Janelia campus for all visitors for the duration of their stay. However, if such accommodation is not available, consider curating a list of nearby lodging options. If possible, negotiate special rates for visitors with your preferred providers. Furthermore, with the compressed timeline of an external visit, it is likely that visiting groups will work beyond the hours that the imaging centre staff will be available. Thus, it is important to ensure their access to all necessary areas to work independently if needed. Visitors should plan to arrive several days prior to the start of imaging to confirm their specimens and regents are in optimal condition and arrange for a second shipment of anything that is found to be nonideal. As can been seen, there are myriad considerations that must be addressed prior to a visit. While not comprehensive, Table 1 provides a list of common issues that may need to be addressed during previsitation planning.

Finally, it is essential, as part of previsit arrangements, that a written user agreement be communicated between the imaging facility and all visiting researchers before a visit begins. Such an agreement sets forth clearly defined expectations and delineations of responsibility for both parties that can be invaluable in resolving/avoiding disputes as well as protecting the integrity and reputation of the imaging facility. The AIC implements such an agreement for all visitors that explicitly establishes several fundamental 'ground rules', including:

1. Expectations for personal behaviour and scientific conduct during the visit.
2. The exact visitation date(s).
3. Requirements surrounding sample and reagent shipment, including that all applicable laws and regulations must be followed when transferring these materials to the imaging centre.
4. Assurances of confidentiality of data and results generated by the visitor, and a clear statement that all data remain the intellectual property of the visiting researchers.
5. A statement indicating that any visit does not constitute an offer of paid employment.
6. Clear enumeration of the financial responsibilities of each party, including instrument time, reagent use, shipping costs and travel expenses, among others.

TABLE 1 Common logistical considerations encountered with handling external visitor specimens and reagents.

Do you have the capacity to safely house, store, grow and/or maintain users' specimens? Do you have quarantine facilities for animal specimens?
Do patient-derived specimens meet ethical standards? Do you have proper licensing if required?
Are specimens free of bloodborne pathogens (BBPs)?
Will institutional biosafety committee (IBC) review be necessary?
Will a recombinant DNA registry be needed?
Will institutional animal care and use committee (IACUC) approval be necessary?
Does your institution allow importation of animals into their facilities?
Do any reagents require special handling/storage or permits? Are any classified as controlled substances?
If biological materials/biologically derived reagents are to be imported, are customs requirements known and being followed? Who will be responsible for ensuring compliance?
Can the appropriate temperature be maintained during shipping?
Does a specimen require any agricultural or wildlife permits for transportation/housing?
Were any specimens prepared using viral transduction or other potentially infectious methods that may pose a risk?
Will decontamination of a microscope be necessary/feasible?
Will the experiment require any specialised ancillary equipment or support that is not available in the facility?
Will the imaging facility provide any lab supplies, reagents or other consumables?

7. Required training that must be completed before work in the laboratory begins.
8. All requirements related to publication of results generated from data acquired during the visit, including authorship, acknowledgement, and sharing of manuscripts for review prior to submission for publication.

The AIC user agreement notes that failure to adhere to these points may result in the cancellation/termination of a visit at the discretion of the Director. We highly encourage imaging facilities to consult with the legal team serving their institution for guidance in authoring their own user agreements. While such agreements will necessarily vary depending on host institutional requirements, quality management guides and resources such as the Enhancing Quality in Preclinical Data (EQIPD) framework can be used to shape facility policies and codify them into formal contracts.[16,17]

6 | DURING THE VISIT: CHECK EARLY, CHECK OFTEN

As with all research projects, extensive preexperimental planning and troubleshooting does not guarantee success. When external visitors begin their imaging experiments, many of the same considerations for local visitors still apply – assessing data quality, tuning experimental parameters, and training the users remain critically important. However, there is one resounding difference: timeline. Because external visitors may be at the imaging facility for only a few weeks as opposed to intermittently visiting over months or years, the process of experimental optimisation must be accelerated. The success of the visit will often hinge on early feedback gained from initial image analysis. Data should be quantitatively evaluated as early and as often as practical to tune microscope and sample preparation parameters and ensure that subsequent datasets can be effectively analysed.

In many cases, several iterations of this loop may be needed. Nimble and frank communication between image analysts, application scientists, and visitors can often salvage a visit that is off to a challenging start. Likewise, when faced with a project that begins as an apparent success, one must still be conscious of the compressed timeline. In the presence of compelling initial data, visitors may be tempted to form new questions and hypotheses mid-visit. However, losing focus of the original goals of the visit risks yielding incomplete data sets that do not conclusively address any question at all. Therefore, a balance must be struck between maintaining focus on the original experimental plan and pursuing unexpected results. In general, rapid and clear feedback has the added benefit of further educating users during their visit on how best to acquire, document, quantify, and interpret microscopy data. This can prove invaluable as a re-enforcement of initial discussions during the technical consultation.

An often underappreciated consideration of a compressed timeline is the importance of the application scientists and microscopists facilitating the visit. Imaging centres that host external visitors need dedicated specialists capable of rapid and often intensive experimental troubleshooting. These team members should be competent microscopists who have strong project management and interpersonal skills. Ideally, technical hosts should be fully available for the visiting group; therefore, it is not advisable for a technical specialist to host multiple external visitor projects simultaneously. Further, the AIC has found that it is important to establish clear expectations with users regarding staff availability beyond typical working hours during a visit. Doing so can be crucial to avoid conflict, and more importantly, guards against staff burnout.

7 | DATA HANDLING: MAKE OR BREAK

7.1 | Data transfer and storage

Put simply, an imaging project is not over when the final image is acquired. A visitor will ideally return to their home institution with a large body of information-rich data. Transferring and safely storing this data can be a costly challenge, particularly with advanced imaging techniques where terabyte datasets are the norm.[18] These difficulties multiply in the case of facilities that cater to external visitors – particularly those from resource-constrained institutions. In the simplest scenarios, it may be feasible to transfer data via portable hard drives. As data size increases, however, the practicality of this strategy rapidly diminishes. Cloud storage services are an intriguing alternative, but their flexibility is tempered by considerably higher costs.[19] A third option, utilised by the AIC, is lendable network attached storage (NAS) devices that accompany users to their home institution. Upon completion of data transfer, the visitor returns the NAS unit to the imaging facility within an agreed timeframe. These drives are widely configurable to match particular needs and available resources. The AIC makes use of consumer-level units with capacities ranging from 20–80 TB and 1 Gb transfer speeds. In general, while requiring more cost up-front to the imaging facility, NAS units provide an efficient data transfer pipeline, particularly for external users who are unable to invest in portable or cloud-based solutions.

Regardless of the chosen data transfer mechanism, visitor capacity to safely store data long-term should be carefully considered at the technical consultation phase. A worst-case scenario exists when informative data is collected, only for it to be irretrievably lost due to poor storage practices. For those who simply lack knowledge of best practices, imaging facility staff can be a valuable educational resource. A more substantial challenge exists for visitors who lack sufficient resources to safely store their own data. Such users may want to consider data sharing services such as Zenodo or FigShare.[20,21] While these services generally offer secure data storage at no cost, any uploaded data will be publicly available, and maximum file sizes are often imposed. In any case, a data transfer and storage plan must be established before an external visitor project proceeds to the data acquisition stage.

7.2 | Data processing, analysis and visualisation

Transfer and storage are only the initial considerations for data handling. Image processing, analysis, and visualisation can be a much more complex and difficult issue. Indeed, a recent survey revealed that many microscopy core facilities struggle to offer sufficient services even to local users.[22] In the case of open-access facilities, practical and logistical issues can compound these difficulties. Therefore, an imaging facility that is considering adopting such a model faces a critical decision from the outset: Should postvisitation data support be offered? And if so, to what extent?

The answer to these questions will largely depend on the technical and personnel resources available within the imaging facility. It is important to consider that the bulk of the image processing, analysis, and visualisation effort will typically occur in the weeks, months, or even years after a visit. These tasks may require high-performance workstations or access to a computational cluster coupled with various, sometimes costly, software packages. Specialised technical knowledge and dedicated personnel time is often necessary to effectively utilise these resources. When considering how to offer data support, there are three generalised models that can be illustrative:

1. **Limited Support**: For imaging facilities with limited resources and personnel, postvisit support may not be feasible. In this case, only the processing, analysis, and visualisation services that are needed to assess data quality during the visit are offered. Visitors are then responsible for their own data analysis through their home institutional resources and/or collaborations with image data scientists. The imaging facility may not be able to support long-term data storage for the visitor.
2. **Hybrid Support**: The AIC primarily utilises a hybrid data support model, whereby facility staff complete the necessary processing steps to view all acquired data. In parallel, analysis and visualisation strategies are discussed, developed, and tested in close collaboration with the visitor. Once a plan is in place, these workflows are transferred to the users so the bulk of the work can be completed at their home institution, with occasional guidance and input by the imaging facility staff.

A limited-term data storage agreement can be put in place during this handoff period.

3. **Comprehensive Support**: Imaging facilities with large, dedicated data-handling infrastructure and staff may be able to offer 'end-to-end' data support. With this model, all aspects of data handling are supported by the imaging facility. Long-term data storage may also be offered. While this model provides users with a fully integrated suite of services, the resources required to maintain the necessary infrastructure and personnel can be prohibitive for many institutions.

Imaging facilities that offer limited or hybrid data support will require users to perform some or all of their data processing, analysis, and visualisation at their home institution. With this in mind, a critical question should always be asked at the earliest technical consultation phase: *'If we can provide a visitor with their ideal data, will they be able to extract meaningful information from it?'*. To answer this question, some conditions need to be met:

The external visitor needs access to sufficient computational resources. Depending on the data size and complexity, computational needs may be significant. A high-performance workstation or computational cluster may be required. It is critical to determine what resources are available to the user at their home institution. A collaboration with data scientists who have sufficient computing power may be necessary.[22] Several web-based image processing and analysis tools have been introduced in recent years that can remove the considerable onus on researchers to provide their own computational resources, including Google Colaboratory, as well as more imaging-focused resources such as IMACEL, the Web Image Processing Pipeline (WIPP), and efforts by the European Open Science Cloud (EOSC-Life).[23–26]

The external visitor needs access to software resources. The availability of open-source image analysis software has never been more plentiful. Packages such as FIJI/ImageJ, CellPose and many others provide powerful, flexible and freely available solutions for a range of needs. [27–34] Some projects, however, may benefit from or even require commercial software. Lacking access to these powerful, but often costly, tools can present a considerable challenge. In many cases, satellite or temporary licensing of these packages may be available from vendors and should be taken advantage of whenever possible.

The external visitor needs access to appropriate expertise. The decision of whether and how much staff time can be committed to postvisit data support is critical and should be discussed and agreed upon before a visit. To ease the burden on imaging facility staff, resources such as NEUBIAS and Software Carpentry can be useful for disseminating data science knowledge.[35,36] Additionally, forums such as Image.sc offer a community-driven setting for users to seek project-specific help from data science experts worldwide.[37]

7.3 | Publication policies and procedures: The final product

While policies for publication authorship vary in their details across institutions, imaging facility acknowledgement is a universal expectation. As stated previously, authorship and acknowledgement policies must be unequivocally communicated prior to accepting a project. In addition, the inclusion of technical errors, uncorrected experimental bias, and poor microscopy methods reporting not only reflect negatively on the imaging facility, but directly contribute to bad science.[38,39] It is therefore imperative to require – through a user agreement – that external users share manuscript drafts for review before submission. The AIC has found that this requirement is welcomed by nearly all users as a mutually beneficial means to promote quality science. However, as a last resort, an imaging centre may request that its staff be removed from authorship or acknowledgement whenever appropriate.

8 | DISCUSSION

As we explore how open-access imaging centres can serve as a mechanism to 'draw' life scientists to cutting edge microscopy technologies, it is reciprocally important to appreciate that open-access platforms can be an equally effective approach to 'push' microscopy technologies to resource-challenged scientific communities. Implicit in the very essence of open-access centres is the confluence of instrument availability, technical expertise, data-handling capacity, data analysis know-how, as well as various ancillary support that is crucial for the success of the project. These are also, unfortunately, the very resources commonly lacking in under-privileged communities. A well-supported, open-access platform set up in a strategic location within such resource-limited regions can therefore overcome these challenges, as illustrated in Figure 4. To that end, the Africa Microscopy Initiative (AMI) stands as an example of a locally controlled, open-access platform that is purpose-built to address such inequities.[40]

However, the notion of open-access to research instruments is an idea that may be unfamiliar to many researchers, particularly in resource-constrained regions. An unfortunate instinctive reaction, upon securing new and costly equipment, is often to restrict its usage to a select few within an institution to minimise the likelihood of equipment damage and misuse. Indeed, based on our communication with many scientists, areas with the most resource constraints often tend to suffer from the least instrument sharing.[41,42] Ultimately, this leads to counter-intuitive and counter-productive outcomes. Based on the successful models instituted by organisations with various funding models and user selection criteria, such as Euro BioImaging, Advanced Bioimaging Support (ABiS), the AIC, AMI and others, it is precisely the opposite of a closed-door approach that stands to be the most widely beneficial in a resource-limited environment. Pooling all available resources available in each region and making them openly available will not only allow researchers to gain access to a collection of technologies that are too costly for a single institution to acquire, but in the process encourage further regional scientific cooperation and collaboration. More importantly, open-access policies also pave the way for the end users to gain access to local imaging expertise, a commodity that can be even scarcer and more valuable.

The rapidly increasing adoption of open-access approaches by various consortia and funding organisations is a testament to their effectiveness to address resource paucity. Consequently, many institutions have likewise considered implementing open-access core facilities. Strategically deployed, they not only serve to champion the spirit of open science – but also become a powerful tool for an institution to showcase its technological capabilities, ultimately cementing regional, if not global leadership.

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